APPENDIX E

EVALUATION OF POTENTIAL PROPELLANTS THAT MAY BE USED BY THE SLLP PROJECT DURING THE PERIOD OF THE LAUNCH OPERATOR LICENSE

As discussed in Section 2.2, during the span of operations considered under the launch operator license (i.e., five years), alternative propellants may be employed on the Upper Stage. Two identified alternatives are Unsymmetrical Dimethylhydrazine (UDMH, or formally 1,1-Dimethylhydrazine) and Boktan (a Russian produced kerosene substitute). Operational evaluations of these products specific to the SLLP project have not been conducted to date. General information, however, is available and has been collected to conduct a preliminary analysis of the environmental consequences of the use of these propellants.

D.1 UDMH

The use of Monomethylhydrazine (MMH) in conjunction with N_2O_4 was evaluated in the February 11, 1999, EA and is used as a reference for comparison here. A potential alternative propellant is Unsymmetrical Dimethylhydrazine (UDMH, or formally 1,1-Dimethylhydrazine) both U.S. Grade and Russian Grade. The quantities of UDMH potentially used in the Upper Stage would be the same as the quantity of MMH currently used in the Upper Stage (approximately 25 to 50 liters, or 7 to 13 gallons).

D.1.1 Comparison of Chemical/Physical and Safety Parameters and Preliminary Analysis

Table D-1 presents several important chemical and physical and safety parameters for UDMH and MMH. A preliminary analysis of the environmental impacts of the use of UDMH, compared with MMH, follows.

Table D-1: Summary of Chemical/Physical and Safety Parameters for UDMH (U.S. and Russian Grade) and MMH

	UDMH	UDMH (Russian Grade)	MMH
General Information:			
Name	1,1-Dimethylhydrazine	1,1-Dimethylhydrazine	Monomethylhydrazine
Chemical formula	$(CH_3)_2NNH_2$	$(CH_3)_2NNH_2$	CH_3NHNH_2
Molecular weight	60.10	60.10	46.07
CAS:	57-14-7	not listed	60-34-4
Composition—	1,1-dimethylhydrazine: 95-99% dimethyl amine: 1-5% water: 0.1 to 1%	1,1-dimethylhydrazine: 98.6% dimethyl amine: 0.5% methyl alcohol: 0.4% water: 0.5%	methylhydrazine: 95-99% water: 1 to 5%
Chemical/Physical Characteristics:			
Boiling point	63°C	63°C	87.5°C
Melting Point	-58°C	-57°C	-52.4°C
Vapor Pressure	157 mm Hg (at 25°C)	not available	49.6 mm Hg (at 25°C)
Vapor Density (air = 1)	2.07	not available	1.59
Specific Gravity	0.80 (at 20°C)	0.790 (at 20°C)	0.874 (at 25°C)

Flash point	-15°C (COC)	-18°C (Abel)	21°C (COC method)
Solubility in Water	miscible	soluble	miscible
Appearance--	clear, colorless liquid with ammonia odor	colorless or light yellow fuming in the air high-toxic liquid with ammonia odor	clear, colorless liquid with amine odor
Handling & Safety Information:			
Reactivity	stable, avoid: heat, sparks, open flame, strong oxidizers	explosive, highly inflammable liquid; easily oxidizes	stable, avoid: temperatures greater than 88°C, static discharge, direct sunlight, heat, sparks strong oxidizers
Decomposition/ Combustion products	carbon monoxide, nitrogen oxides	soot, carbon monoxide, nitrogen oxides	carbon monoxide, nitrogen oxides
Hazard classification	classified as IB flammable liquid, corrosive	classified as extremely dangerous substances, Class 1 of danger by effect on organism [a/] (GOST 12.1.007-76)	classified as IB flammable liquid
Health Hazard Data:			
Exposure limits and effects	OSHA PEL: 1mg/m^3 (skin) Oral LD_{50} (rat) 122 mg/kg; not considered carcinogenic	Toxicity level (max. permissible) 0.1mg/m^3 in production rooms air; 0.001mg/m^3 in atmospheric air—maximum single and daily average	OSHA PEL: 0.35mg/m^3 (skin) Oral LD_{50} (rat) 32 mg/kg; considered mutagenic but not carcinogenic

NOTE: a/ Class 1 GOST is the most dangerous.

Sources:

S. P. Korolev Rocket and Space Corporation Energia, *Certificate of Material Safety Unsymmetrical Dimethyl Hydrazine*, Nov. 10, 2000.

NIOSH, *Pocket Guide to Chemical Hazards: Methyl hydrazine*, www.cdc.gov/niosh/npg/npgd0419.html as of Dec. 18, 2000.

NIOSH, *Pocket Guide to Chemical Hazards: 1-1 Dimethylhydrazine*, www.cdc.gov/niosh/npg/npgd0227.html as of Dec. 18, 2000.

NIOSH, *Manual of Analytical Methods (NMAM): 1-1Dimethylhydrazine, Method 3515*, Fourth Edition, Aug. 15, 1994.

NIOSH, *Manual of Analytical Methods (NMAM): Monomethylhydrazine, Method 3510*, Fourth Edition, Aug. 15, 1994.

Olin Corporation, *Material Safety Data Sheet: Unsymmetrical dimethylhydrazine*, http://msds.pdc.cornell.edu/msds/siri/msds/h/q197/q293.html, Dec. 18, 2000.

Olin Corporation, *Material Safety Data Sheet: Monomethylhydrazine*, http://msds.pdc.cornell.edu/msds/siri/msds/h/q384/q195.html, Dec. 18, 2000.

UDMH and MMH are both hydrazines with several differences in chemical and physical parameters (e.g., boiling point, specific gravity, vapor pressure, flash point). The two fuels, however, are similar in terms of reactivity, products of combustion (based on N_2O_4 as an oxidizer), exposure limits, and hazard classification. Consequently, the handling of these fuels at Home Port and on board the Launch Platform would be equivalent to procedures undertaken for previous missions, although containers and labeling requirements may vary based on relevant regulatory requirements. Equally important, the combustion emissions of the two fuels will be similar (there will be a variation in the stoichiometric ratios—i.e., the quantitative relationship between substances in processes involving chemical change) and will occur at the same altitudes as described in the February 11, 1999 EA.

D.1.2 Effect on Home Port & Marine Operations

The change from MMH to UDMH does not have a large impact on Home Port permitting. The following documents need to be amended prior to UDMH arrival on-site:

a) Hazardous Material Inventory (EPCRA), Long Beach Department of Health (CUPA)
b) Business Emergency Plan, Long Beach Fire Department
c) Operations Manual for the Transfer of Hazardous Material in Bulk, USCG
d) Integrated Contingency Plan

The following document will need to reflect the change in 2002:

e) Annual Emissions Inventory (Year 2001), SCAQMD

The following document will not require changes because thresholds are not exceeded:

f) Risk Management Plan, Long Beach Department of Health (CUPA)

Regarding the physical changes to Home Port or ship-board operations, Kvaerner Govan's HVAC contractor, Novenco, had specific scrubber filter elements designed, constructed, and delivered that would capture and properly neutralize vapors from UDMH. Following approval of the use of UDMH, these scrubbers will be installed at the SLLP facilities.

D.2 BOKTAN

The use of kerosene (Russian grade) in conjunction with LOX was evaluated in the February 11, 1999, EA and is used as a reference for comparison here. A potential alternative propellant is Boktan, a Russian produced kerosene substitute classified as a hydrocarbon product composed mainly of cycloalkanes. The quantities of Boktan potentially used in the Upper Stage would be approximately the same as the quantity of kerosene currently used in the Upper Stage (4,325 kg. or 9,515 lbs.).

D.2.1 Comparison of Chemical/Physical and Safety Parameters and Preliminary Analysis

Table D-2 presents several important chemical and physical and safety parameters for Boktan and kerosene. A preliminary analysis of the environmental impacts of the use of Boktan, compared with kerosene, follows.

Table D-2: Summary of Chemical/Physical and Safety Parameters for Kerosene (U.S. and Russian Grade) and Boktan

	Boktan	Kerosene	Kerosene (Russian Grade)
General Information:			
Chemical class	cycloalkanes	hydrocarbon fraction	hydrocarbon fraction
Common name	boktan (or naphthenes)	kerosene	naphthyl
Elemental composition	CH_2	$CH_{1.96}$ (average)	no information
Composition—	“boktan” or cycloalkanes –	complex mixture of	mixture of petroleum

	98% dicyclobutylidene – 0.5% light impurities – 1.3% heavy impurities – 0.2% water – 0.05%	hydrocarbons blended to meet product specifications; composition varies and includes C9 to C16 hydrocarbons; common components include hydrodesulfurized kerosene, hydrotreated distillate light, straight run kerosene; functional and performance additives may also be present	fractions with boiling point ranges; 98% is distilled at a temperature not higher than 270°C aromatic hydrocarbons 5.0% sulfur 0.01% 4-methyl 2,6 ditertiary butylphenol 0.005 to 0.006% resins 2,0 % dissolved water 0.0006%
Chemical/Physical Characteristics:			
Boiling point	134°C	151°C to 301°C	no information
Melting Point	-62.7°C to -54.5°C	-18°C	no information
Vapor Pressure	no information	0.5 m Hg at 20°C	0.3 mm Hg at 17°C
Vapor Density (air = 1)	no information	4.5	no information
Specific Gravity	0.829	0.80 to 0.81	0.833
Flash point	19°C	38°C PM minimum	61°C
Solubility in Water	no information	insoluble	insoluble
Appearance	colorless clear liquid	colorless to pale straw, or red oily liquid with characteristic odor	colorless transparent liquid with a specific odor of gasoline
Handling & Safety Information:			
Reactivity	highly stable; incompatible with oxidizers, explosives and inflammable substances	stable under normal conditions; incompatible with sources of ignition	inert liquid, explosion hazard
Decomposition/ Combustion products	carbon oxides	carbon oxides	carbon oxides
Hazard classification	Class 3 of danger,[a/] moderately hazardous substances (per GOST 12.1.007-76)	DOT Hazard Class 3 or Combustible Liquid	Low toxic substance, Class 4 (per GOST 12.1.007-76)
Health Hazard Data:			
Exposure limits and effects	toxicity level: max. permissible concentration in production rooms = 5 mg/m^3	NIOSH proposed limit of 100 mg/m^3 for 8 hr.; ACGIH proposed exposure limit of 100 mg/m^3	maximum allowable concentrations of vapors in production rooms = 300 mg/m^3, in populated areas =5 mg/m^3 ; and in water 0.1mg/dm^3.

NOTE: a/ Class 1 GOST is the most dangerous.

Sources:

S. P. Korolev Rocket and Space Corporation Energia, *Certificate of Material Safety Boktan*, Sept. 9, 1999.

S. P. Korolev Rocket and Space Corporation Energia, *Certificate of Material Safety Naphthyl*, Sept. 25, 1997

T.W. Brown Oil Co., Inc., *Material Safety Data Sheet for Kerosene*, www.brownoil.com/msdskerosene.htm, as of February 6, 2001.

The most significant difference between Boktan and kerosene is in chemical classification. Although both hydrocarbons, kerosene is a blend of mainly normal, straight-chain alkanes whereas Boktan is mainly a mixture of cycolalkanes. The ratio of carbon to hydrogen is roughly the same, however. Regarding material stability, both Boktan and kerosene are stable liquids incompatible with sources of ignition or explosion. Hazard classifications for Boktan and kerosene are comparable, although Boktan has a lower exposure limit in occupational settings. The combustion products of the two propellants will be similar (carbon dioxide and possibly carbon monoxide; and the stoichiometric ratios should be relatively similar). Furthermore, emissions would occur at the same altitudes as described in the February 11, 1999, EA.

D.2.2 Effect on Home Port & Marine Operations

It is assumed that Boktan would be handled in the same manner as kerosene is currently handled—i.e., it would not be stored on Home Port property. The Integrated Contingency Plan would have to be updated with a name change (Boktan for kerosene), and any associated Emergency Procedures that may differ than for kerosene would have to be reviewed and documented. Regarding the Operations Manual for the Transfer of Hazardous Materials in Bulk, a name change and any associated emergency procedures that may be different would need to be recorded. Also, Boktan would need to be added to the Annual Emissions Inventory. Finally, Boktan may need to be included in the Risk Management Plan. This may be considered only an update, however, as kerosene has been classified as fuel and Boktan may remain within the same classification.